INDOOR AIR QUALITY REASSESSMENT

Crowell Elementary School
26 Belmont Avenue
Haverhill, Massachusetts 01830

Prepared by:
Massachusetts Department of Public Health
Center for Environmental Health
Bureau Emergency Response/Indoor Air Quality Program
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Background/Introduction

At the request of Jeffrey Dill, Supervisor of Maintenance and Energy Management, Haverhill Public Schools (HPS), the Massachusetts Department of Public Health's (MDPH) Center for Environmental Health (CEH) conducted a reassessment of indoor air quality at the Crowell Elementary School (CES), 26 Belmont Avenue, Haverhill, Massachusetts. On April 8, 2005, a visit to conduct an indoor air quality assessment was made to the CES by Michael Feeney, Director of CEH's Emergency Response/Indoor Air Quality (ER/IAQ) Program. The purpose of the visit was to determine the efficacy of remediation measures taken.

The CES is a two-story brick building constructed in 1891. The eight-room facility underwent renovations in the 1980s. Classrooms are located on the first and second floor. The nurse's office and other office spaces are located on the first floor. The basement consists of an art room, a music room, library, and cafeteria. Windows throughout the building are openable.

Actions on MDPH Recommendations

As mentioned, CEH staff had previously visited the building and issued a report with recommendations to improve indoor air quality (MDPH, 2004). A summary of actions taken on previous recommendations is included as Appendix A.

Methods

Air tests for carbon monoxide, carbon dioxide, temperature and relative humidity were conducted with the TSI, Q-Trak, IAQ Monitor, Model 8551. Air tests for airborne particle matter with a diameter less than 2.5 micrometers were taken with the TSI, DUSTTRAK™ Aerosol Monitor Model 8520. Screening for total volatile organic compounds (TVOCs) was conducted using a Thermo Environmental Instruments Inc., Model 580 Series Photo Ionization Detector (PID). CEH staff performed visual inspection of building materials for water damage and/or microbial growth. Moisture content of water damaged wooden trim was measured with a Delmhorst, BD-2000 Model, Moisture Detector equipped with a Delmhorst Standard Probe.

Results

The school houses approximately 130 students in kindergarten through second grade and has approximately 10 staff members. Tests were taken during normal operations and results appear in Table 1.

Discussion

Ventilation

It can be seen from Table 1 that carbon dioxide levels were above 800 parts per million (ppm) in five of twelve areas surveyed, indicating adequate ventilation in most areas of the school. However, some areas were unoccupied during air sampling; low occupancy can reduce carbon dioxide levels. At the time of the assessment, no mechanical ventilation was operating. Windows in some classrooms were closed, despite fair weather conditions (air sampling was conducted on a clear, sunny day with minimal wind).

Fresh air in classrooms was originally supplied by a unit ventilator (univent) system (Picture 1). Univents are designed to draw air from outdoors through a fresh air intake located on the exterior walls of the building (Picture 2) and return air through an air intake located at the base of each unit (Figure 1). Obstructions to airflow, such as furniture located in front of and/or materials stored on univents seen during the original assessment, had been removed in most classrooms. As discussed, univents were deactivated in all classrooms throughout the school. In order for univents to provide fresh air as designed, these units must remain activated and allowed to operate. Mr. Jeff Dill reported these univents were in the process of being repaired.

The exhaust ventilation system at the CES is reportedly atypical of a school building of its age. In the previous assessment, the ventilation system was described as a hybrid mechanical/gravity system, where the univent system was identified as the mechanical component and an interior vent system (Picture 3) identified as a gravity exhaust system. These observations were based on experiences from other indoor air quality assessments conducted in buildings of similar age. After a long discussion with Mr. Dill and a reexamination of the interior vents, it appears that the vents previously thought to be exhaust vents are actually heating vents connected to the building's furnace. The configuration of the heating system is as follows:

- In a typical gravity ventilation system, the interior wall has two vents, one for supply and a separate vent for exhaust. At the CES, each room has only one vent.
- The interior wall vents appear to be part of the original construction of the building, circa 1891. Univents were not in general use until 1920.
- The univents installed in the building likely dates to the 1930s. It is likely that the univents were installed as part of a reconfiguration of the school's heating system.

It appears that the classroom univents that provide tempered fresh air are the only functional mechanical ventilation components at the CES. No functioning exhaust vent system exists in the building. The sealed vents are actually artifacts of a previously existing heating system. The lack of an exhaust system coupled with deactivated univents would tend to result in an accumulation of indoor pollutants. Even with univents operating in the current configuration, a lack of exhaust can allow pollutants to buildup and be re-circulated by the univents. Further, this type of ventilation system cannot be balanced.

The Massachusetts Building Code requires that each room have a minimum ventilation rate of 15 cubic feet per minute (cfm) per occupant of fresh outside air or have openable windows (SBBRS, 1997; BOCA, 1993). The ventilation must be on at all times that the room is occupied. Providing adequate fresh air ventilation with open windows and maintaining the temperature in the comfort range during the cold weather season is impractical. Mechanical ventilation is usually required to provide adequate fresh air ventilation.

Carbon dioxide is not a problem in and of itself. It is used as an indicator of the adequacy of the fresh air ventilation. As carbon dioxide levels rise, it indicates that the ventilating system is malfunctioning or the design occupancy of the room is being exceeded. When this happens, a buildup of common indoor air pollutants can occur, leading to discomfort or health complaints. The Occupational Safety and Health Administration (OSHA) standard for carbon dioxide is 5,000 parts per million parts of air (ppm). Workers may be exposed to this level for 40 hours/week, based on a time-weighted average (OSHA, 1997).

The MDPH uses a guideline of 800 ppm for publicly occupied buildings. A guideline of 600 ppm or less is preferred in schools due to the fact that the majority of occupants are young and considered to be a more sensitive population in the evaluation of environmental health status. Inadequate ventilation and/or elevated temperatures are major causes of complaints such as respiratory, eye, nose and throat irritation, lethargy and headaches. For more information concerning carbon dioxide, see Appendix B.

Indoor temperature measurements ranged from 68^{o} F to 72^{o} F, which were close to the MDPH recommended comfort range in most classrooms. The MDPH recommends that indoor air temperatures be maintained in a range of 70^{o} F to 78^{o} F in order to provide for the comfort of building occupants. It is difficult to control temperature and maintain comfort in a building without operating mechanical exhaust vents. In many cases concerning indoor air quality, fluctuations of temperature in occupied spaces are typically experienced, even in a building with an adequate fresh air supply.

Indoor relative humidity measurements ranged from 36 to 47 percent, which were within or at the lower end of the MPDH recommended comfort range. The MDPH recommends a comfort range of 40 to 60 percent for indoor air relative humidity. Relative humidity levels in the building would be expected to drop during the winter months due to heating. The sensation of dryness and irritation is common in a low relative humidity environment. Low relative humidity is a very common problem during the heating season in the northeast part of the United States.

Microbial/Moisture Concerns

Water damaged portions of interior wall described in the previous report were repaired and found to be free of excessive moisture. Gutters and downspouts were repaired.

Other IAQ Evaluations

Indoor air quality can be negatively influenced by the presence of respiratory irritants, such as products of combustion. The process of combustion produces a number of pollutants, where the pollutant produced is dependent on the material combusted. Common combustion emissions include carbon monoxide, carbon dioxide, water vapor and smoke (fine airborne particulate matter). Of these materials, exposure to carbon monoxide and particulate matter with a diameter of 2.5 micrometers (μm) or less (PM2.5) can produce immediate, acute health effects upon exposure. To determine whether combustion products were present in the school environment, MDPH staff obtained measurements for carbon monoxide and PM2.5 during the April 8, 2005 visit.

Carbon monoxide is a by-product of incomplete combustion of organic matter (e.g., gasoline, wood and tobacco). Exposure to carbon monoxide can produce immediate and acute health affects. Several air quality standards have been established to address carbon monoxide and prevent symptoms from exposure. The MDPH established a corrective action level concerning carbon monoxide in ice skating rinks that use fossil-fueled ice resurfacing equipment. If an operator of an indoor ice rink measures a carbon monoxide level over 30 ppm, taken 20 minutes after resurfacing within a rink, that operator must take actions of reduce carbon monoxide levels (MDPH, 1997).

ASHRAE has adopted the National Ambient-Air Quality Standards (NAAQS) as one set of criteria for assessing indoor air quality and monitoring of fresh air introduced by HVAC systems (ASHRAE, 1989). The NAAQS are standards established by the US EPA to protect the public health from six criteria pollutants, including carbon monoxide and particulate matter (US EPA, 2000). As recommended by ASHRAE, pollutant levels of fresh air introduced to a building should not exceed the NAAQS (ASHRAE, 1989). The NAAQS were adopted by reference in the Building Officials & Code Administrators (BOCA) National Mechanical Code of 1993 (BOCA, 1993), which is now an HVAC standard included in the Massachusetts State Building Code (SBBRS, 1997). According to the NAAQS, carbon monoxide levels in the outdoor air should not exceed 9 ppm in an eight-hour average (US EPA, 2000).

Carbon monoxide should not be present in a typical, indoor environment. If it *is* present, indoor carbon monoxide levels should be less than or equal to outdoor levels. Outdoor carbon monoxide concentrations were non-detectable (ND) (Table 1). Carbon monoxide levels measured in the school were also ND.

The US EPA also established NAAQS limits for exposure to particulate matter. Particulate matter is airborne solids that can be irritating to the eyes, nose and throat. The NAAQS originally established exposure limits to particulate matter with a diameter of 10 μm or less (PM10). According to the NAAQS, PM10 levels should not exceed 150 microgram per cubic meter ($\mu g/m^3$) in a 24-hour average (US EPA, 2000). These standards were adopted by both ASHRAE and BOCA. Since the issuance of the ASHRAE standard and BOCA Code, US EPA proposed a more protective standard for fine airborne particles. This more stringent, PM2.5 standards requires outdoor air particle levels be maintained below 65 $\mu g/m^3$ over a 24-hour average (US EPA, 2000). Although both the ASHRAE standard and BOCA Code adopted the PM10 standard for evaluating air quality, MDPH uses the more protective proposed PM2.5 standard for evaluating airborne particulate matter concentrations in the indoor environment.

Outdoor PM2.5 concentrations were measured at 25 $\mu g/m^3$ (Table 1). PM2.5 levels measured in the school ranged from 11 to 40 $\mu g/m^3$, below the NAAQS PM2.5 level. A number of mechanical devices and/or activities that occur in schools can generate particulate during normal operations. Sources of indoor airborne particulates may include but are not limited to particles generated during the operation of fan belts in the HVAC system, cooking in the cafeteria stoves and microwave ovens; use of photocopiers, fax machines and computer printing devices; operation of an ordinary vacuum cleaner and heavy foot traffic indoors. As previously discussed, neither mechanical supply nor exhaust were operating at the school at the time of the assessment. Without the operation of mechanical ventilation systems, a buildup of common indoor air pollutants can occur.

Indoor air quality can also be negatively influenced by the presence of materials containing volatile organic compounds (VOCs). VOCs are carbon-containing substances that have the ability to evaporate at room temperature. Frequently, exposure to low levels of total VOCs (TVOCs) may produce eye, nose, throat and/or respiratory irritation in some sensitive individuals. For example, chemicals evaporating from a paint can stored at room temperature would most likely contain VOCs. In an effort to determine whether VOCs were present in the building, air monitoring for TVOCs was conducted. An outdoor air sample was taken for comparison. Outdoor TVOC concentrations were ND (Table 1). Indoor TVOC concentrations were also ND.

In an effort to identify materials that can potentially increase indoor TVOC concentrations, MDPH staff examined classrooms for products containing these respiratory irritants. Please note, TVOC air measurements are only reflective of the indoor air concentrations present at the time of sampling. Indoor air concentrations can be greatly impacted by the use of TVOC containing products. Several classrooms contained dry erase boards, dry erase cleaners, and dry erase board markers. Materials such as dry erase markers and dry erase board cleaners may contain VOCs, such as methyl isobutyl ketone, n-butyl acetate and butyl-cellusolve (Sanford, 1999), which can be irritating to the eyes, nose and throat.

Other conditions that can affect indoor air quality were noted during the assessment. Pathways exist for boiler room odors and other materials to move into occupied areas. The boiler room can be accessed through a long, narrow hallway in the basement. There is no door separating the boiler room hallway from other portions of the basement. This allows for odors and materials from this room to move into other portions of the basement.

Further evaluation of a building component identified in the previous assessment (Picture 4) confirmed that it was a door for the school's abandoned incinerator. The structure would be connected to the chimney located on the eastern half of the CES, with the chimney above the western half servicing the furnace. For these reasons, it is unlikely that this structure would serve as a means for odors and particles to move into upper level areas of the building.

Conclusions/Recommendations

In view of the findings at the time of the visit, the following recommendations are made:

1. Examine the feasibility of providing a mechanical exhaust ventilation system for the building.
2. Use openable windows to create air exchange. Care should be taken to ensure windows are properly closed at night and weekends to avoid the freezing of pipes and potential flooding.
3. All ventilation systems that are operable throughout the building (e.g., gym, auditorium, classrooms) should operate continuously during periods of school occupancy and independent of thermostat control to maximize air exchange.

References

ASHRAE. 1989. ASHRAE Standard: Ventilation for Acceptable Indoor Air Quality. Sections 5.11, 5.12. American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. Atlanta, GA.

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OSHA. 1997. Limits for Air Contaminants. Occupational Safety and Health Administration. Code of Federal Regulations. 29 C.F.R 1910.1000 Table Z-1-A.

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SBBRS. 1997. Mechanical Ventilation. State Board of Building Regulations and Standards. Code of Massachusetts Regulations. 780 CMR 1209.0.

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Picture 1

Classroom univent

Picture 2

Exterior fresh air intake

Picture 3

Grated heat supply vent

Picture 4

Incinerator Door Previously Identified as Dumbwaiter

Crowell Elementary School **Indoor Air Results**

26 Belmont Avenue, Haverhill, MA 01830 **April 8, 2005**

Table 1

Location/ Room	Occupants in Room	Temp (°F)	Relative Humidity (%)	Carbon Dioxide (ppm)	Carbon Monoxide (ppm)	TVOCs (ppm)	PM2.5 (µg/m3)	Windows Openable	Ventilation		Remarks
									Supply	Exhaust	
Background		61	44	422	ND	ND	25				
cafeteria	1	71	43	581	ND	ND	6	Y # open: 0 # total: 8	N	N	repaired water damage.
teacher's lounge	0	70	41	510	ND	ND	5	Y # open: 0 # total: 4	N	N	soda machines.
2	20	70	41	761	ND	ND	11	Y # open: 2 # total: 8	Y univent (off)	N	
1	0	71	37	611	ND	ND	10	Y # open: 1 # total: 8	Y univent (off)	N	DEM.

ppm = parts per million
µg/m3 = micrograms per cubic meter

AD = air deodorizer
AP = air purifier
aqua. = aquarium

AT = ajar ceiling tile
BD = backdraft
CD = chalk dust
CP = ceiling plaster
CT = ceiling tile
DEM = dry erase materials

design = proximity to door
FC = food container
G = gravity
GW = gypsum wallboard
M = mechanical
MT = missing ceiling tile

NC = non-carpeted
ND = non detect
PC = photocopier
PF = personal fan
plug-in = plug-in air freshener
PS = pencil shavings

sci. chem. = science chemicals
TB = tennis balls
terra. = terrarium
UF = upholstered furniture
WD = water damage
WP = wall plaster

Comfort Guidelines

Carbon Dioxide -	< 600 ppm = preferred
	600 - 800 ppm = acceptable
	> 800 ppm = indicative of ventilation problems
Temperature -	70 - 78 °F
Relative Humidity -	40 - 60%

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Location/ Room	Occupants in Room	Temp (°F)	Relative Humidity (%)	Carbon Dioxide (ppm)	Carbon Monoxide (ppm)	TVOCs (ppm)	PM2.5 (µg/m3)	Windows Openable	Ventilation		Remarks
									Supply	Exhaust	
4	18	72	38	766	ND	ND	14	Y # open: 1 # total: 8	Y univent (off)	N	DEM.
3	19	71	37	654	ND	ND	12	Y # open: 0 # total: 8	Y univent (off)	N	DEM.
7	20	70	47	1314	ND	ND	18	Y # open: 0 # total: 8	Y univent (off)	N	
5	0	72	36	891	ND	ND	11	Y # open: 0 # total: 8	Y univent (off)	N	
8	18	71	46	1462	ND	ND	16	Y # open: 0 # total: 8	Y univent (off)	N	TB, items.

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									Supply	Exhaust	
6	25	72	35	977	ND	ND	15	Y # open: 1 # total: 6	Y univent	N	Hallway DO, DEM.
library	0	69	40	513	ND	ND	5	Y # open: 0 # total: 2	Y univent (off)	N	
art	15	68	38	551	ND	ND	8	Y # open: 0 # total: 7	Y univent (off)	N	

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Appendix A

Actions on MDPH Recommendations
Massachusetts Department of Public Health
Crowell Elementary School, Haverhill, MA

The following is a status report of action(s) taken on MDPH recommendations based on reports from building management, office staff, documents, photographs and MDPH staff observations.

1. Continue with remediation efforts in the basement areas.

   Action Taken: All areas of water damage in basement were repaired.

2. Consider consulting a heating, ventilation and air conditioning (HVAC) engineer concerning the operability of univents. Consideration should be given to replacing univents.

   Action Taken: According to Jeffery Dill, univents were either repaired or in process of being repaired. Univents could not be evaluated since the boiler system was deactivated.

3. Consider re-establishing a functional exhaust ventilation system for classrooms, if univents are to be replaced.

   Action Taken: Refer to the Ventilation section of main reassessment report.

4. Use openable windows to create air exchange. Care should be taken to ensure windows are properly closed at night and weekends to avoid the freezing of pipes and potential flooding.

Action Taken: Windows were open in some rooms. Windows should be opened in during school hours to enhance airflow in the building during fair weather.

5. Consider repointing brickwork.

   Action Taken: Repairs were made to basement, and water damaged materials were removed. Consideration should be given to evaluate the exterior wall for the building for repair, as needed.

6. Operate all ventilation systems that are operable throughout the building (e.g., classrooms) continuously during periods of school occupancy and independent of thermostat control to maximize air exchange.

   Action taken: Refer to the Ventilation section of main assessment report.

7. Ensure plants have drip pans. Examine drip pans periodically for mold growth and disinfect with an appropriate antimicrobial where necessary. Keep plants away from the air stream.

   Action taken: Plants were removed from classrooms examined.

8. Relocate or consider reducing the amount of materials stored in classrooms to allow for more thorough cleaning of classrooms. Clean items regularly with a wet cloth or sponge to prevent excessive dust build-up.

   Action taken: All classrooms had materials removed from vicinity of univents. Most classrooms had materials removed to increase ability to clean.

Appendix A

9. Clean chalkboard/dry erase marker trays regularly to prevent the build-up of excessive chalk dust and particulate.

   Action taken: Chalk trays were free of accumulated dust.

10. Store cleaning products properly and out of reach of students.

    Action taken: Cleaning products were removed from classrooms.